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2 **Home-to-Grid Domain Expert Working Group**
3
4 **Requirements**
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13 **Table of Contents**

1 Introduction

The GridWise Architecture Council and the National Institute of Standards and Technology (NIST) have formed Domain Experts Working Groups (DEWGs) to develop a report for the United States Congress about the state of standards for electric smart grids. The Home-to-Grid DEWG (H2G DEWG) is investigating communications between utilities and home devices to facilitate demand response programs that implement energy management.

The H2G DEWG named a Requirements Subcommittee to specify requirements for residential demand response systems. The Requirements Subcommittee started with material derived from "UtilityAMI 2008 Home Area Network System Requirements" published by the UCA® International Users Group. The UtilityAMI requirements are summarized in Annex A of this report.

The requirements defined in this report facilitate the implementation of demand response. Therefore, this report begins with an overview of demand response techniques. This overview is based on a published ISO/IEC[1] Technical Report, ISO/IEC 15067-3 "Model of an energy management system for the Home Electronic System."[2] As explained in the overview, there are various methods for implementing demand response. The choices will vary by utility to achieve the load shape that aligns with supply limitations, transmission and distribution capabilities, regulatory constraints, and business considerations.

An important factor for the success of demand response is the development of appropriate gateways, controllers, and Home Area Network (HAN) Devices. Utilities can specify what they would like in such products, but must also motivate manufacturers to design and market them. Utilities deal with many suppliers of industrial and business products, but most have not cultivated relationships in the consumer product industries. The annual market for consumer electronics is almost $200 billion[3] and for home appliances is about $25 billion[4]. Both markets include hundred of manufacturers that produce thousands of new

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[1]   ISO = International Organization for Standardization

IEC = International Electrotechnical Commission

ISO/IEC = Designation of international standards related to information technology

The missions of ISO and the IEC are to foster international trade and commerce.

As a member of the World Trade Organization (WTO), the United States has agreed to use international standards unless it writes "higher standards if there is scientific justification." [per WTO agreement]

[2] ISO/IEC standards may be purchased from the American National Standards Institute at http://webstore.ansi.org.

[3] Market size per Consumer Electronics Association (www.ce.org).

[4] Market size per Hoovers, a D&B Company (www.hoovers.com).

79   products each year. Thus, there are many options for negotiating product specifications
80   adapted for energy management provided there is motivation from public policy and from
81   utilities.

82   2   Terminology

83   The following terminology is included to establish a common understanding about key
84   elements in a home demand response system.

85   *2.1 Energy Management Controller*

86   A set of functions that manage energy consumption as an agent for the customer.
87   Physically, these functions may be embedded in a residential gateway, in an appliance, or in
88   a stand-alone device.

89   *2.2 HAN Devices*

90   A device located in the home that can be connected to a home network. The device may be
91   a home appliance, consumer electronics device, sensor, actuator, user interface, or
92   controller. Examples of such devices typically involved with energy management include
93   thermostats, HVAC (heating, ventilation, and air-conditioning) equipment, displays, and
94   major appliances (called "white goods" by the appliance industry). The home network may
95   be wired or wireless. For real-time energy management applications, the home network is
96   linked to a utility network, possibly via a residential gateway. Appliances that function as
97   HAN Devices are sometimes called "smart appliances."

98   *2.3 Residential Gateway*

99   A communications function that interconnects two networks operating with different
100   communications protocols. The two protocols may differ by media type, digital data
101   encoding, timing, and message sets. The purpose of the gateway is to translate and deliver
102   messages from one network to the other.

103   For utility applications, this gateway is sometimes called a Utility Gateway. The functions
104   of a utility gateway may be embedded in a stand-alone device, in a utility meter, or in a
105   device in the home such as an appliance. Multiple gateways may be located in a house for
106   the delivery of various services such as demand response, entertainment, Internet, and
107   telephony. The general architecture of a residential gateway is specified in the following
108   international standard: ISO/IEC 15045-1, "A Residential gateway model for Home
109   Electronic System." According to this standard, the responsibilities of the gateway include
110   protocol translation and provisions for ensuring the privacy, safety, and security of
111   consumers.

112   UtilityAMI specifies the utility-related functions of a utility gateway using the term "Energy
113   Services Interface." The Energy Services Interface specification focuses on security of

114   messages communicated between the utility and HAN Devices involved with energy
115   management.

116 **3   Demand Response (DR)**

117 *3.1   Demand Response Introduction*

118   Electricity consumption patterns have peaks daily and seasonally. During weather
119   extremes of heat and cold the demand for electricity rises sharply. In the U.S. the
120   average rate of power generation is only about 46% of the peak generation that occurs
121   during these situations. Some utilities need to keep relatively expensive generators
122   running to meet this peak. These peak generators are called Spinning Reserves.

123   Ideally, the utilities would like to maintain the supply of electricity sufficient to meet any
124   demand. However, this is becoming less practical because of public resistance to new
125   power plants and government rules controlling environmental pollution. The expensive
126   Spinning Reserves could be idled if customers evened out their power consumption so
127   the peak is flattened. Utilities have developed demand-side management (DSM) methods
128   to influence the customer demand for power in order to align with the available supply.

129   The objective of DSM is to reduce peak demands for electricity by about 5% up to 100
130   hours per year, according to a December 2005 report of the Demand Response and
131   Advanced Metering Coalition (DRAM)[5]. The Electric Power Research Institute
132   estimated in 2001 that "… a 2.5% reduction in electricity demand statewide could reduce
133   wholesale spot prices in California by as much as 24%; a 10% reduction in demand might
134   slash wholesale price spikes by half."[6]

135   *3.2   What is Demand-Side Management (DSM)*

136   DSM programs initially focused on providing incentives for using less electricity with
137   more efficient appliances. Some programs offer rebates for switching from tungsten to
138   compact fluorescent lamps, for adding building insulation, and for purchasing energy
139   efficient appliances.

140   Utilities have developed more deterministic methods for influencing the demand through
141   Demand Response (DR). DR uses incentive-based and indirect methods for controlling
142   how much electricity is consumed during a specified time interval by water heaters, air-

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[5] Demand Response and Advanced Metering Coalition (DRAM), comments filed in Docket AD06-2, December 19, 2005, 5. Reported in FERC, *Assessment of Demand Response and Advanced Metering Staff Report*, Docket AD06-2-000, August 2006.

[6] Taylor Moore, "Energizing Customer Demand Response in California," *EPRI Journal*, Summer 2001, p. 8.

143 conditioners, and industrial equipment. The more innovative methods of load control
144 depend on market forces for exerting control by varying the price of electricity.

145 DR offers effective methods of DSM, but is currently applied only to about 8% of all
146 U.S. customers, according to a FERC (Federal Energy Regulatory Commission) survey
147 reported in December 2008[7].

3.3 Demand Response via utility control

149 DR includes programs and technologies to modify customer demand for energy directly
150 by remote control of customer appliances (called *Direct Load Control*) or indirectly
151 through pricing incentives or event notifications.

152 Some large industrial customers volunteer for lower electric rates in exchange for
153 deliberate service interruption. When the utilities are facing a supply limitation, perhaps
154 on a hot summer day, they order these volunteers to remove equipment from the power
155 grid. The analogous program for residential customers is Direct Load Control, where the
156 operation of selected devices like air-conditioners and water heaters is interrupted. In a
157 typical version of Direct Load Control the utility sends a signal via the power line or
158 radio to a switch that cycles the air-conditioner off for about 15 minutes or the water
159 heater off for about two hours.

160 Direct Load Control requires prior arrangements with customers for permission and
161 equipment installation. Many customers in the U.S. are offered rebates of up to $10 a
162 month for participating in direct load control. Of the 5% of U.S. customer under load
163 control, most are participating in direct control.

3.4 Demand Response via electricity pricing

165 An indirect method of Load Control is based on electric rates that vary over time or a
166 notice to customers of a pending event, such as a partial supply interruption, requiring
167 consumption reductions. In the simplest scheme, the utility establishes a peak and off-
168 peak price where the ratio of on-to-off peak pricing is high enough to motivate customers
169 to defer heavy power-consuming appliance usage to the off-peak times.   For this
170 technique, called *Local Load Control*, to be effective the customer must:

171 • Remember the time period for off-peak pricing of power.

172 • Know which appliances consume relatively large amounts of energy.

173 • Not be significantly inconvenienced by deferring appliance operation to off-
174 peak times.

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[7] "FERC Report Marks Significant Progress in Demand Response, Advanced Metering," News
Release from FERC, R-08-70, December 29, 2008.

175 Much more effective DR is possible by exploiting microprocessor-based intelligence at
176 the customer premises. *Distributed Load Control* combines local and direct control with
177 much increased flexibility. The utility has the opportunity to change prices at will by
178 following the wholesale market price of electricity to reflect actual utility costs.
179 Intelligent appliances respond with minimal user involvement or inconvenience.

180 The following scenario is an example of how a user might interact with an integrated
181 Distributed Load Control system:

182   It is 4 PM and the user is about to run the dishwasher. The following options
183   appear on the appliance display panel:

184   *1. Wash dishes now.*

185   *2. Delay wash by 3 hours and save 25¢*

186   *3. Delay wash by 6 hours and save 50¢*

187 The user makes a simple decision based on criteria that are understandable: "Do I need
188 the dishes cleaned in the next three hours (perhaps for a dinner party at 7 PM), or can I
189 wait and save some money?" This makes buying energy as simple as shopping at a retail
190 store.

191 ### 3.5   Implementing effective demand response

192 Figure 1 shows a feasible Distributed Load Control residential implementation. The
193 utility sends pricing data electronically to all houses in real-time over a network such as
194 the Internet. This pricing signal enters the house through the Utility Gateway, a version
195 of a residential gateway. This gateway interconnects a public network using telephone,
196 cable TV, power lines, or radio with a home network. The gateway may be a separate
197 device, as shown in Figure 1, or could be integrated with other gateways, controllers, or
198 even inside an electric meter.
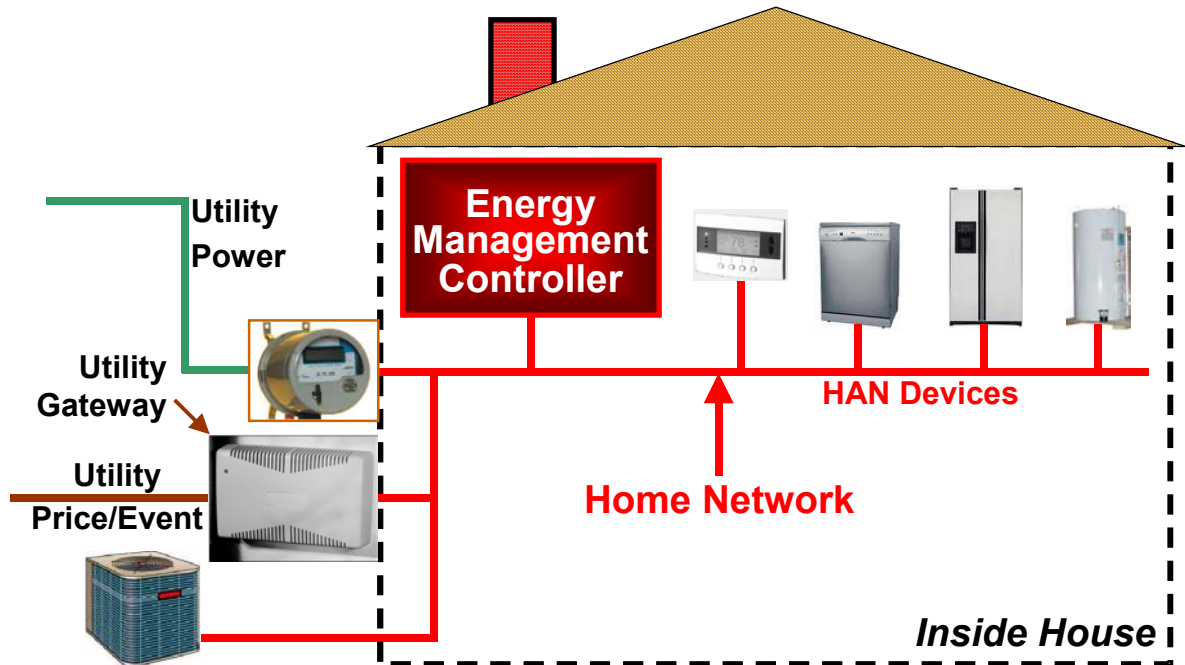
Figure 1 – Distributed Load Control System
(Utility Gateway courtesy of GridPlex, Inc.)

Control signals are sent from the Utility Gateway to the major energy consuming appliances via the home network to control when and in what modes they operate. The element in this system responsible for regulating energy consumption is the Energy Management Controller (EMC). As noted in the Terminology section of this report, the EMC may be a discrete physical device or the EMC functions may embedded in the gateway, in an appliance, or in a controller providing a diversity of home services.

The EMC performs specialized computing functions by receiving the electricity rate data from the residential gateway and applying sophisticated software algorithms to determine which appliances to operate and when. The functions of the EMC are illustrated in Figure 2.

Figure 2 – Energy Management Controller

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215 The EMC is programmed to determine how and when to operate appliances based on the
216 cost of energy, the energy requirements of the appliances, and user inputs. The user
217 might specify a monthly energy budget (for example, $100 per month) and preferences
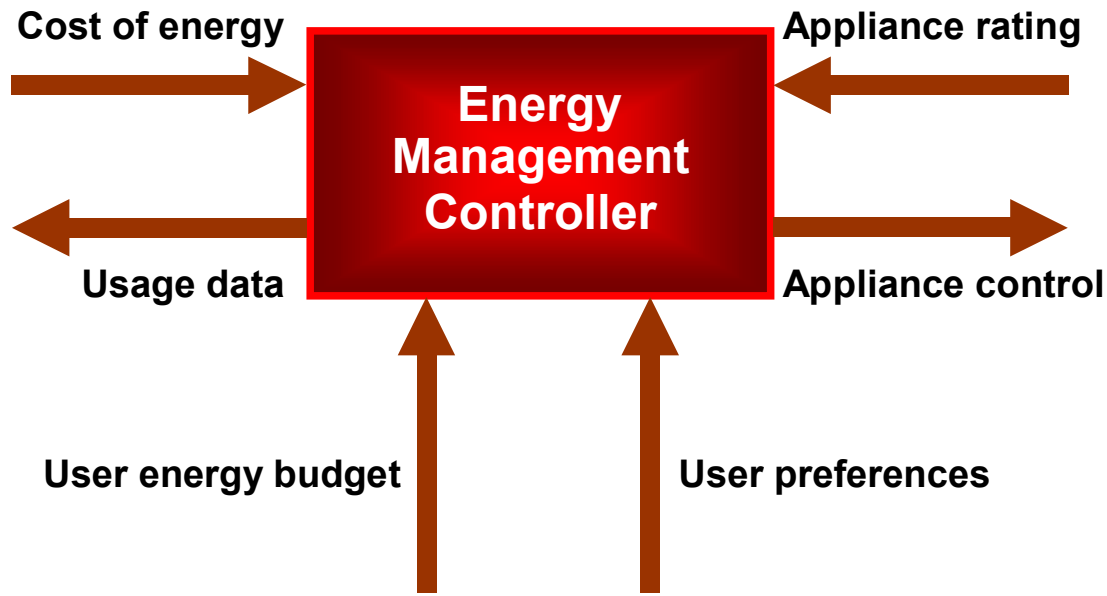218 (shower at 8 AM, air conditioning at 6 PM, pool at 8 PM, etc.). The customer should
219 always be able to override decisions of the EMC. After processing these data, the
220 controller issues signals that are distributed over a home network to the relevant
221 appliances. Intelligent appliances that can operate in energy conserving modes can
222 improve the effectiveness of a Distributed Load Control system.

223 It is possible to implement distributed load control by sending utility prices and event
224 notifications directly to smart appliances. This is called "prices to devices." Such
225 appliances would need to be programmed to understand the price or event messages and
226 to respond accordingly with reduced consumption where appropriate. However, the
227 ability to allocate limited energy (or a limited budget for energy) among appliances
228 according to consumer preferences is lost without the coordination provided by the EMC.

229 **4   Assumptions**

230 The following assumptions help organize the H2G requirements.

231 1. The Energy Management Controller makes local decisions about energy consumption
232 based on customer preferences, customer budget, appliance energy and operational
233 requirements, energy costs, and energy events (such as a temporary supply limitation).
234 This is called "distributed load control."

235 2. Utilities or third-party service suppliers may optionally contract with customers to
236 manage energy consumption remotely by controlling HAN Device energy consumption.

237 This is called "direct load control." An Energy Management Controller may be omitted
238 for direct load control or may have limited functionality.

239 3. The utility or an intermediary energy management service provider is responsible for
240 sending data about energy costs and energy events, or for sending control signals for
241 direct load control.

242 4. The only required data sent to the utility are aggregated energy consumption data for
243 billing. The customer decides how often consumption data are sent to the utility based
244 on the tariffs offered by the utility and the tariff chosen by the customer. The data sent
245 may be disaggregated for specific appliances (such as HVAC) depending on the tariff
246 chosen.

247 5. The Energy Management Controller and associated appliances, some of which may
248 include network connections ("smart appliances" or "HAN Devices"), may be furnished
249 by the utility or by third parties, or may be purchased from retailers by consumers.

250 **5 General Requirements**

251 These requirements are generic and have been extracted from the UtilityAMI requirements.
252 Additional requirements specific to the DR solution chosen by UtilityAMI can be found in
253 Annex A.

254 1. The Energy Management Controller shall accept data from the utility. Such data shall
255 include price data and event data. Such data may include control signals if the customer
256 chooses direct load control for some or for all loads. For direct control these control
257 signals may bypass an Energy Management Controller and be sent between the
258 residential gateway and the HAN device.

259 2. Utilities, manufacturers of Energy Management Controllers, and makers of appliances
260 under direct load control shall agree on a communications protocol that includes
261 acknowledgement of message transmission for data integrity, verification of data
262 validity (data sent from a legitimate source), and execution (or execution failure) of a
263 specified command.

264 3. The HAN network implementing demand response shall be based on a communications
265 protocol that sends acknowledged data packets and acknowledged messages (composed
266 of one or more data packets). A packet or message shall be acknowledged if is contains
267 no detectable error using error detection and correction mechanisms such as checksums,
268 cyclical redundancy checks (CRCs), or more complex methods.   A retransmission
269 mechanism to recover damaged packets and/or messages shall be provided.   When
270 applicable, the routing options should be optimized and diversity in pathways shall be
271 provided for media subject to fluctuation (such as a radio link).

272 4. The HAN Device shall report any customer override of control from an Energy
273 Management Control or directly from the utility.

274   5. The Energy Management Controller shall delay restoration of operational state (after a
275   power failure) based on a pre-configured time (e.g., random number). Smart appliances
276   may be programmed for delayed restoration without an Energy Management Controller.

277   6. The Energy Management Controller shall include a power cycle function to reboot the
278   device.

279   7. The Energy Management Controller shall provide a user reset input, which returns the
280   device to its pre-installation state by a simple user operation, such as pushing a button.

281 **6   Requirements based on features chosen by consumer**

282 The following optional features may be needed in HAN Devices or in an Energy
283 Management Controller depending on the type of tariff the customer chooses and flexibility
284 desired. Manufacturers and retailers may offer HAN Devices and Energy Management
285 Controllers with various capabilities at a variety of price points and levels of potential
286 energy savings. (This is similar to the choices offered by consumer electronics
287 manufacturers.)

288   1. Respond to request to cycle operational state (i.e., duty cycle).

289   2. Respond to request to limit operational mode based on thresholds, set-points or triggers
290   (e.g., price points). This can support "prices to devices" if no Energy Management
291   Controller is present.

292   3. Respond to requests for variable output (e.g., load limiting, energy savings mode).

293   4. Measure instantaneous demand (e.g., W).

294   5. Measure accumulated consumption (e.g., Wh).

295   6. Measure accumulated production (e.g., Wh) for locally generated power.

296   7. Measure consumption per interval (e.g., Wh, BTU, CCF, HCF).

297   8. Measure production per interval (e.g., Wh) for locally generated power.

298   9. Store interval measurements (e.g., 30 days of interval reads).

299   10. Allow interval configuration (e.g., 15 Minutes).

300   11. Monitor energy state (e.g., state of charge), where applicable (e.g., for home devices
301   with storage capability).

302   12. Measure capacity (e.g., W, Volt-Amps), where applicable (e.g., for home devices with
303   storage capability).

304   13. Monitor the device state (e.g., operational, stand-by, maintenance).

305 14. Monitor the operational mode (e.g., charging, discharging).

306 15. Measure power quality (e.g., frequency, neutral voltage, harmonic content).

307 16. Monitor environmental state (e.g., temperature, motion, wind).

308 17. Monitor the operational mode of connected home devices (e.g., duty cycle).

309 18. Monitor environmental impact (e.g., CO_2).

310 19. Provide visual indicators that indicate operational state (e.g., commissioned, event
311   status, device state). The indicator data may be sent to display devices or terminals
312   elsewhere in the house or made available for remote viewing, perhaps on a cell phone.

313 20. Provide non-visual sensory feedback (e.g., motion, vibration, audible).

314 21. Provide a sight and hearing impaired interface.

315 22. Provide a user configurable display.

316 23. Accept user configurations.

317 24. Accept user preferences (e.g., Celsius/Fahrenheit, color, language).

318 25. Provide alarm notifications (e.g., price threshold, event messages, internal device
319   alarms).

320 26. Display application-specific information (e.g., cost, consumption, environmental
321   impact).

322 27. Accept application-specific configurations (e.g., pre-configured periods (e.g., hour, day,
323   week), configurable periods (e.g., interval length, Time-of-Use (TOU) period), variable
324   periods (e.g., Critical Peak Price period).

325 28. For battery-powered devices, provide a battery life indicator.

326 **7   Payment options**

327 Options for an Energy Management Controller that provides local payment facilities, like
328 prepay or bill-paying options.

329 1. Display application-specific information (e.g., payment credit, remaining account
330   credit).

331 2. Accept payment data from the consumer.

8 Requirements for customer education application

Options for an application in an Energy Management Controller or in a HAN device that provides consumption and cost details. These values are intended to provide customer education and guidance for effective energy conservation. They are not necessarily accurate enough for revenue billing. The set of parameters defined here enables a range of educational products. Thus, the product manufacturer can choose subsets appropriate for a target market depending on age or anticipated skill set.

1. The application shall calculate a HAN Device energy cost of accumulated energy consumption as monetary value (e.g., $/kWh * accumulated kWhrs = $).

2. The application shall calculate a HAN Device energy cost of instantaneous power consumption as a monetary value per time interval, (e.g., $/Wh * instantaneous W= $/hr).

3. The application shall calculate a HAN Device cost for Hourly Energy rates.

4. The application shall calculate a HAN Device energy cost for rate tiers/energy blocks.

5. The application shall calculate a HAN Device energy cost for Time-of-Use (TOU) energy rates.

6. The application shall calculate a HAN Device cost for Critical Peak Pricing (CPP).

7. The application shall calculate a HAN Device cost for capacity billing rates.

8. The application shall calculate costs for other billing determinants (e.g., monthly Consumer charges, taxes & franchise fee, surcharges, discounts, ratcheted demand, bond charges).

9. The application shall accept aggregated consumption and rate information from user-configurable sources (e.g., Energy Management Controller, residential gateway, AMI System, and/or human-machine interface).

10. The application shall calculate and forecast a HAN Device consumption based on user defined parameters (e.g., estimated kWh/month).

11. The application shall calculate and forecast a HAN Device production based on user-defined parameters (e.g., estimated kWh/month).

12. The application shall forecast a HAN Device estimated cost calculation based on user-defined parameters (e.g., monthly consumption at current rate/usage).

13. The application shall calculate a HAN Device consumption based on user-defined parameters (e.g., historical reporting).

364 14. The application shall calculate a HAN Device production based on user-defined
365   parameters (e.g., historical reporting).

366 15. The application shall calculate and/or predict a HAN Device environmental impact
367   based on user-defined parameters (e.g., historical carbon footprint, forecasted carbon
368   credits earned).

369 16. The application shall supply a method for local billing resolution (e.g., orphaned billing
370   charge, consumption debits/credits).

371 17. The application shall calculate and suggest methods to optimize energy consumption
372   and cost based on user-defined parameters (e.g., programmable communicating
373   thermostat thresholds, lighting settings, pool pump cycling).

374 18. The application shall calculate a HAN Device relative efficiency (e.g., comparison can
375   be based on historical data, baseline at install, manufacturer's parameters,
376   industry/governmental standards, other devices, other premises).

377 19. The application shall calculate available load for demand reduction based on user-
378   defined parameters (e.g., percentage of load available for various response scenarios).

379 20. The application shall calculate user-defined thresholds for consumption, production, and
380   cost (e.g., if aggregated consumption reaches a certain level, an alert is generated).

381 **9   Requirements for Direct Load Control**

382 Options for HAN Devices that may be chosen by the consumer for participation in direct
383 control offered by the utility or by a third-party supplier.

384 1. Respond to requests to cease operational state (e.g., open contact).

385 2. Respond to requests to resume operational state (e.g., close contact).

386 3. Acknowledge receipt of control signal.

387 4. Acknowledge execution of control request.

388 5. Acknowledge execution failure of request (i.e., exceptions).

389 6. Signal any consumer-initiated overrides.

390 7. Respond to request to cease operation state at a specific time.

391 8. Respond to request to resume operation state at a specific time.

392 9. HAN Devices under direct load control shall accept and display data source
393   configurations from the Residential Gateway or from other HAN Devices.

394 10. The Residential Gateway shall store a list of available, commissioned HAN Devices in
395   the premise and make that list available to the utility upon request if required in the
396   direct load control agreement between the utility and the customer.

397 11. The Residential Gateway shall provide a configurable HAN filtering function that filters
398   based on allowable message types.

399 12. The Residential Gateway shall provide a configurable HAN filtering function that filters
400   messages based on structural integrity of the message.

401 13. The Residential Gateway shall provide a configurable HAN filtering function that filters
402   based on allowable message rates.

403 14. The Residential Gateway shall protect a HAN Device from malicious code (e.g., buffer
404   overflow protection, limit executable code exposure).

405 15. The Residential Gateway shall provide non-repudiation mechanisms for devices and
406   users.

407 16. The Residential Gateway shall provide a mechanism for source identification of data
408   (e.g., HAN Device and utility data).

409 17. HAN Device shall supply accurate time keeping and counter functions.

410 18. HAN Device shall not act on expired signals (e.g., message validity duration or
411   sequence).

412 19. HAN Device shall accept network time synchronization from the Residential Gateway.

413 20. HAN Device shall display on packaging utility compatibility guidance to verify that a
414   HAN Device is compatible with a particular DR direct load control system.

415 21. The following are recommended for all direct control devices (they are required by
416   UtilityAMI). The choice to implement may depend on device costs, market conditions,
417   and negotiations between manufacturers and utilities.

418   a) HAN Device Manufacturer shall include installation documentation that includes
419   instructions for installation (e.g., placement), commissioning, and registration,
420   including any external dependencies.

421   b) HAN Device Manufacturer shall include a HAN Device user's manual in the Device
422   packaging.

423   c) HAN Device Manufacturer shall include Manufacturer contact information in the
424   Device packaging.

425   d) HAN Device Manufacturer shall supply technical support services (e.g., help desk,
426   web site).

427 e) HAN Device shall have a selfcheck (i.e., initialization) function that notifies the
428   Installer that the HAN Device is functioning properly.

429 f) Residential gateway shall have a configurable ability to log all utility to gateway
430   system communications.

431 g) When the HAN Device is rebooted, HAN device shall reset to the configured (i.e.,
432   post-installation commissioning and registration) state and shall reestablish
433   communication with the Energy Services Interface.

434 h) HAN Device shall have a user operable testing function that is equivalent to the self-
435   testing function.

436 i) HAN Device shall supply a maintenance port for field diagnostics.

437 j) HAN Device shall simulate utility events for diagnostic purposes.

438 k) HAN Device shall supply network management functions for diagnostic purposes.

439 l) For battery-powered devices, HAN Device shall communicate low-battery state to
440   the utility system.

441 m) HAN Device Manufacturer shall supply and support a flaw remediation process.

442 n) HAN Device shall support a communications feedback mechanism (i.e., ping).

443 10 Network configuration and management

444 1. The HAN shall include methods for assigning network addresses to attached devices
445   such as a Residential Gateway, Energy Management Controller, and HAN Devices.

446 2. The HAN shall include methods for newly attached devices to associate with energy
447   management applications offered by an in-home Energy Management Controller
448   (distributed control) or by the utility via a Residential Gateway (direct control).
449   Association includes product identification and product capabilities for participating in
450   energy management applications. This process is called commissioning.

451 3. HAN Devices shall acknowledge successful commissioning requests (i.e., provide
452   acknowledgement to the requesting HAN Device).

453 4. The Energy Management Controller (distributed control) or the Residential Gateway
454   (direct control) shall have the ability to accept or reject HAN Device requests.

455 5. HAN Device shall acknowledge successful commissioning requests (i.e., provide
456   acknowledgement to the requesting HAN Device).

457 6. HAN Device shall provide notification to the Installer of the commissioning status.
458   Status conveyed shall be either: successful/unsuccessful.

459 7. The Energy Management Controller (distributed control) or the Residential Gateway
460   (direct control) shall maintain an updated list of commissioned (i.e., connected) HAN
461   Devices.

462 8. The Energy Management Controller (distributed control) or the Residential Gateway
463   (direct control) shall have the ability to remove HAN Devices from participating in DR.

464 9. After loss of power, HAN Device shall return to post configuration state (i.e., shall
465   persist communication and registration configurations).

466 10. When a HAN Device is triggered (e.g. Power-on, button), HAN Device shall provide
467   the Energy Management Controller (distributed control) or the Residential Gateway
468   (direct control) with device-specific information to identify the device functions subject
469   to remote management. Such data might include device address and device type.

470 11. The Energy Management Controller (distributed control) or the Residential Gateway
471   (direct control) shall have the ability to accept or reject a HAN Device request based on
472   device type.

473 12. The Energy Management Controller (distributed control) or the Residential Gateway
474   (direct control) shall have the ability to remove HAN Devices from participating in DR.

475 13. The Energy Management Controller (distributed control) or the Residential Gateway
476   (direct control) shall have the ability to query the status of HAN Devices.

477 **11 Network security**

478 1. Control signals, consumption data, and on-line billing exchanged shall be protected
479   using tools comparable to Internet commerce including authorization, authentication,
480   and encryption, as appropriate.

481 2. Communications between the Residential Gateway and the utility should be designed to
482   prevent attacks such as replay, masquerading, delay, spoofing, sequence change, and
483   deletion attacks. This is especially important for direct load control where the utility or
484   third-party service provider controls home appliances remotely. Annex A contains
485   specific security requirements chosen by UtilityAMI.

486 3. When HAN devices are connected to a HAN network, they are configured to exchange
487   messages with an Energy Management Controller or with a service outside the house for
488   direct load control. If the HAN device is registering with an external party providing
489   direct load control, appropriate security measures must be included.

490 4. The first line of defense for security is the Residential Gateway. As noted in the section
491   of this report describing the gateway, the ISO/IEC 15045-1, "A Residential gateway
492   model for Home Electronic System" international standard includes specifications for
493   security. The following are additional relevant international standards:

494   a) ISO/IEC 24767-1, "Information technology – Home network security – Part 1:
495   Security requirements"

496   b) ISO/IEC 24767-2 Ed.1.0, "Information technology – Home network security - Part
497   2: Internal security services – Secure communication protocol for middleware
498   (SCPM)"

499   c) ISO/IEC 14762, "Information technology – Functional safety requirements for
500   Home Electronic Systems (HES)"

Annex A - UtilityA MI HAN System Requirements

UtilityAMI OpenHAN Task Force

Extracted from Version 1.04 of August 19, 2008

A.1   Categories of requirements

The name of each requirement category is listed with the number of requirements in parentheses.

- Application Control requirements (13)

- Application Measure (15)

- Application Human-Machine Interface (16)

- Application Process (20)

- Communication Commissioning (13)

- Communication Control (10)

- Security Access (13)

- Security Integrity (16)

- Security Account (9)

- Security Registration (13)

- Performance (14)

- Operations, Maintenance, and Logistics; Manufacturing and Distribution (12)

- Operations, Maintenance, and Logistics; Installation (4)

- Operations, Maintenance, and Logistics; Manage and Maintain (10)

A.2   List of OpenAMI Requirements

A.2.1   Application Control requirements (13)

1. HAN Device shall accept control signals from the Utility.

2. HAN Device shall respond to requests to cease operational state (e.g., open contact).

526   3. HAN Device shall respond to requests to resume operational state (e.g., close contact).

527   4. HAN Device shall acknowledge receipt of control signal.

528   5. HAN Device shall acknowledge execution of control request.

529   6. HAN Device shall acknowledge execution failure of request (i.e., exceptions).

530   7. HAN Device shall signal any consumer-initiated overrides.

531   8. HAN Device shall respond to request to cease operation state at a specific time.

532   9. HAN Device shall respond to request to resume operation state at a specific time.

533   10. HAN Device shall delay restoration of operational state based on a pre-configured time
534   (e.g., random number).

535   11. HAN Device shall respond to request to cycle operational state (i.e., duty cycle).

536   12. HAN Device shall respond to request to limit operational mode based on thresholds, set-
537   points or triggers (e.g., price points).

538   13. HAN Device shall respond to requests for variable output (e.g., load limiting, energy
539   savings mode)

540   *A.2.2   Application Measure (15)*

541   1. HAN Device shall measure instantaneous demand (e.g., W).

542   2. HAN Device shall measure accumulated consumption (e.g., Wh).

543   3. HAN Device shall measure accumulated production (e.g., Wh).

544   4. HAN Device shall measure consumption per interval (e.g., Wh, BTU, CCF, HCF).

545   5. HAN Device shall measure production per interval (e.g., Wh).

546   6. HAN Device shall store interval measurements (e.g., 30 days of interval reads).

547   7. HAN Device shall allow interval configuration (e.g., 15 Minutes).

548   8. HAN Device shall monitor energy state (e.g., state of charge), where applicable (e.g., for
549   HAN Devices with storage capability).

550   9. HAN Device shall measure available capacity (e.g., W, Volt-Amps), where applicable
551   (e.g., for HAN Devices with storage capability).

552   10. HAN Device shall monitor the device state (e.g., operational, stand-by, maintenance).

553   11. HAN Device shall monitor the operational mode (e.g., charging, discharging).

554   12. HAN Device shall measure power quality (e.g., frequency, neutral voltage, harmonic
555   content).

556   13. HAN Device shall monitor environmental state (e.g., temperature, motion, wind).

557   14. HAN Device shall monitor the operational mode of other devices (e.g., duty cycle).

558   15. HAN Device shall monitor environmental impact (e.g., CO_2).

A.2.3 Application Human-Machine Interface (16)
(559)

560   1. HAN Device shall provide visual indicators that indicate operational state (e.g.,
561   commissioned, registered, event status, device state).

562   2. HAN Device shall provide a power cycle input, which reboots the device.

563   3. HAN Device shall provide a user reset input, which returns the device to its pre-
564   installation state (e.g., button).

565   4. HAN Device shall provide an alphanumeric display that indicates operational state (e.g.,
566   LCD screen).

567   5. HAN Device shall provide nonvisual sensory feedback (e.g., motion, vibration, audible).

568   6. HAN Device shall provide a sight and hearing impaired interface. NA

569   7. HAN Device shall provide a user configurable display.

570   8. HAN Device shall accept user configurations.

571   9. HAN Device shall accept user preferences (e.g., Celsius/Fahrenheit, color, language).

572   10. HAN Device shall provide alarm notifications (e.g., price threshold, event messages,
573   internal device alarms).

574   11. HAN Device shall accept Utility data source configurations (e.g., Energy Services
575   Interface, other HAN Devices).

576   12. HAN Device shall display Utility data source configurations (e.g., Energy Services
577   Interface, other HAN Devices).

578   13. HAN Device shall display application-specific information (e.g., cost, consumption,
579   environmental impact, payment credit, remaining account credit).

580   14. HAN Device shall accept application-specific configurations (e.g., preconfigured
581   periods (e.g., hour, day, week), configurable periods (e.g., interval length, TOU period),
582   variable periods (e.g., Critical Peak Price period).

583   15. For battery-powered devices, HAN Device shall provide a battery life indicator.

584   16. HAN Device shall accept payment data from the consumer.

585   ### *A.2.4   Application Process (20)*

586   1. The application shall calculate a HAN Device's energy cost of accumulated energy
587   consumption as monetary value (e.g., \$/kWh * accumulated kWhrs = \$).

588   2. The application shall calculate a HAN Device's energy cost of instantaneous power
589   consumption as a monetary value per time interval, (e.g., \$/Wh * instantaneous W=
590   \$/hr).

591   3. The application shall calculate a HAN Device's cost for Hourly Energy rates.

592   4. The application shall calculate a HAN Device's energy cost for rate tiers/energy blocks.

593   5. The application shall calculate a HAN Device's energy cost for Time-of-Use (TOU)
594   energy rates.

595   6. The application shall calculate a HAN Device's cost for Critical Peak Pricing (CPP).

596   7. The application shall calculate a HAN Device's cost for capacity billing rates.

597   8. The application shall calculate costs for other billing determinants (e.g., monthly
598   Consumer charges, taxes & franchise fee, surcharges, discounts, ratcheted demand, bond
599   charges).

600   9. The application shall accept aggregated consumption and rate information from user-
601   configurable sources (e.g., Energy Services Interface, AMI System, and/or HMI).

602   10. The application shall calculate and forecast a HAN Device's consumption based on user
603   defined parameters (e.g., estimated kWh/month).

604   11. The application shall calculate and forecast a HAN Device's production based on user-
605   defined parameters (e.g., estimated kWh/month).

606   12. The application shall forecast a HAN Device's estimated cost calculation based on user-
607   defined parameters (e.g., monthly consumption at current rate/usage).

608   13. The application shall calculate a HAN Device's consumption based on user-defined
609   parameters (e.g., historical reporting).

610   14. The application shall calculate a HAN Device's production based on user-defined
611   parameters (e.g., historical reporting).

612 15. The application shall calculate and/or predict a HAN Device's environmental impact
613   based on user-defined parameters (e.g., historical carbon footprint, forecasted carbon
614   credits earned).

615 16. The application shall supply a method for local billing resolution (e.g., orphaned billing
616   charge, consumption debits/credits).

617 17. The application shall calculate and suggest methods to optimize energy consumption
618   and cost based on user-defined parameters (e.g., PCT thresholds, lighting settings, pool
619   pump cycling).

620 18. The application shall calculate a HAN Device's relative efficiency (e.g., comparison can
621   be based on historical data, baseline at install, manufacturer's parameters,
622   industry/governmental standards, other devices, other premises).

623 19. The application shall calculate available load for demand reduction based on user-
624   defined parameters (e.g., percentage of load available for various response scenarios).

625 20. The application shall calculate user-defined thresholds for consumption, production, and
626   cost (e.g., if aggregated consumption reaches a certain level, an alert is generated).

627 ### A.2.5 Communication Commissioning (13)

628 1. HAN Device shall accept network configuration data which allows for private Utility
629   networking (e.g., private address/ID)

630 2. HAN Device shall accept commissioning configuration data by the manufacturer (e.g.,
631   link key).

632 3. HAN Device shall accept commissioning configuration from the Installer.

633 4. When Energy Services Interface is triggered (e.g., Allow Join Command), HAN Device
634   location-specific/ contact-specific data shall be provided to other HAN Devices in the
635   premise.

636 5. When a HAN Device is triggered (e.g. Power-on, button), HAN Device shall provide
637   the Energy Services Interface with device specific information including device ID and
638   device type.

639 6. When a HAN Device is triggered (e.g. power on, button), HAN Device shall provide the
640   Energy Services Interface with device specific Utility information, including network
641   ID, gateway ID, and Utility ID, if pre-configured with Utility information.

642 7. Energy Services Interface shall have the ability to accept or reject the request based on
643   device type.

644 8. Energy Services Interface shall have the ability to accept or reject device requests based
645   on Utility specific information (e.g., network ID, gateway/ Utility ID)

646 9. HAN Device shall acknowledge successful commissioning requests (i.e., provide
647   acknowledgement to the requesting HAN Device).

648 10. When a HAN Device is communicating with the Energy Services Interface, HAN
649   Device shall indicate link connectivity.

650 11. HAN Device shall provide notification to the Installer of the commissioning status.
651   Status conveyed shall be either: successful/unsuccessful.

652 12. Energy Services Interface shall maintain an updated list of commissioned (i.e.,
653   connected) HAN Devices.

654 13. Energy Services Interface shall have the ability to remove HAN Devices from the Utility
655   HAN.

656 ### *A.2.6   Communication Control (10)*

657 1. HAN Device shall accept network organization messages from the Energy Services
658   Interface (e.g., gateway location, routing table, address).

659 2. HAN Device shall accept network organization messages from peer devices (e.g.,
660   hidden node).

661 3. HAN Device shall use the most reliable path to the Energy Services Interface (e.g.,
662   based on signal strength/quality).

663 4. HAN Device shall only use Utility designated routes.

664 5. HAN Device shall have the ability to automatically adapt to communications
665   interference through detection and analysis of environmental conditions (e.g., channel
666   hopping, channel avoidance, signal-to-noise ratio).

667 6. HAN Device shall include a data integrity mechanism for all communications (e.g.,
668   checksum)

669 7. Energy Services Interface shall have the ability to activate and deactivate its HAN
670   communication.

671 8. HAN Device shall communicate its availability (i.e., `heartbeat') to the Energy Services
672   Interface at least once per day.

673 9. HAN Device shall have a configurable availability communication (i.e., heartbeat)
674   frequency to the Energy Services Interface.

675 10. Energy Services Interface shall store a list of available, commissioned HAN Devices in
676   the premise and make that list available to the AMI System upon request.

A.2.7 Security Access (13)

1. Energy Services Interface shall provide access control (i.e., logical segmentation) to Utility applications, data, and services (e.g., control data, consumer specific consumption data).

2. HAN Device shall control access to persistent Utility HAN data (data at rest).

3. HAN Device shall control access to transmitted Utility HAN data (data in transit).

4. HAN Device shall provide protection of Utility HAN data while being processed (data in processing) (e.g., trusted processor).

5. HAN Device shall control access to data in accordance with a configurable Utility security policy (e.g., users, applications, devices, data access-read/write).

6. Energy Services Interface shall provide mechanisms to enforce a policy based on least privilege (i.e., explicit authorization).

7. Energy Services Interface shall have the ability to enforce policy periods (time constraints) for security policy elements (e.g., maintenance/firmware window).

8. HAN Device shall provide methods to query and report access control data settings.

9. HAN Device shall provide access control methods which prevent known attacks, including replay, man-in-the-middle, delay, spoofing, sequence change, and deletion attacks.

10. HAN Device shall implement mechanisms to prevent unintended disclosure of source/originator data to unauthorized principals.

11. HAN Device shall implement controls that limit access to audit information.

12. HAN Device shall support confidentiality and access controls that employ cryptographic operations (e.g., digital signatures).

13. HAN Device shall support confidentiality and access controls that employ cryptographic keys (e.g., encryption authentication, or digital signatures).

A.2.8 Security Integrity (16)

1. HAN Device shall protect the integrity of the HAN system (e.g., shall not adversely impact the operations of the HAN system by introducing malicious or unintended activity).

2. Energy Services Interface shall provide a configurable HAN filtering function that filters based on allowable message types.

708   3. Energy Services Interface shall provide a configurable HAN filtering function that filters
709   messages based on structural integrity of the message.

710   4. Energy Services Interface shall provide a configurable HAN filtering function that filters
711   based on allowable message rates.

712   5. HAN Device shall detect unauthorized modification of security-related data during
713   storage

714   6. HAN Device shall detect unauthorized modification of data during network transit (e.g.,
715   check sums and hashes).

716   7. HAN Device shall detect unauthorized modification of data attributes (e.g., modification
717   to a message type).

718   8. HAN Device shall attempt to correct unauthorized modification of data attributes (e.g.,
719   NAK, resend)

720   9. HAN Device shall only accept data from an authorized, trusted source (e.g., Energy
721   Services Interface, certified EMS).

722   10. HAN Device shall protect the HAN from malicious code (e.g., buffer overflow
723   protection, limit executable code exposure).

724   11. HAN Device shall separate security critical functionality and data from non-security
725   critical system data.

726   12. HAN Device shall validate the source of HAN security policy.

727   13. HAN Device shall detect unauthorized modification of HAN security policy.

728   14. HAN Device shall detect unauthorized modification of audit data.

729   15. HAN Device shall validate the integrity of all software updates, including source,
730   structure, and version.

731   16. HAN Device shall use tamper resistant hardware (e.g., epoxy, TPM).

732   ### A.2.9   Security Account (9)

733   1. HAN Device shall alert the Energy Services Interface of all detected, security-related
734   activities, including access control, authentication, and integrity violations.

735   2. HAN Device shall audit and store all security-related activities, including access control
736   violations, authentication activities, etc.

737   3. HAN Device shall provide, at a minimum, the following information for all detected
738   security events: date and time of the event, type of event, device/user identity.

739   4. HAN Device shall provide the AMI System access to audit data.

740   5. Energy Services Interface shall provide non-repudiation mechanisms for devices and
741   users.

742   6. Energy Services Interface shall provide a mechanism for source identification of data
743   (e.g., HAN and AMI System data).

744   7. Energy Services Interface shall provide the capability to audit both system and user
745   operations as defined by the HAN security policy.

746   8. HAN Device shall provide the ability to perform searches, sorts, and filters of audit data
747   based on date and time, type and/or user identity.

748   9. HAN Device shall provide the capability to identify mandatory and configurable audit
749   elements (In this context, mandatory refers to audit elements which are always enabled
750   and configurable refers to audit elements which can be enabled or disabled at the
751   discretion of the Consumer or Utility).

A.2.10 Security Registration (13)

752

753   1. HAN Device shall support mutual authentication.

754   2. HAN Device shall authenticate the source of all control signals.

755   3. HAN Device shall provide a mechanism that allows for multiple and configurable
756   authentication materials (e.g., device ID, device type, key, serial key, Utility ID, and
757   device configuration).

758   4. HAN Device shall be configured with Utility-approved or Utility provided
759   authentication materials (e.g., certificate, key).

760   5. HAN Device shall not send authentication materials over the network in an insecure
761   fashion (e.g., do not transmit passwords or keys in the clear).

762   6. HAN Device shall be compatible with a Utility-defined registration process.

763   7. HAN Device shall provide a means to update (i.e., change, reconstitute, rollover)
764   authentication materials.

765   8. Energy Services Interface shall allow registration revocation for connected HAN
766   Devices.

767   9. Energy Services Interface shall support a configurable registration and expiration period
768   (e.g., registration timeout, registration persistence).

769   10. HAN Device shall use security services (i.e., cryptographic services) which are either
770   FIPS approved or NIST-recommended.

771 11. HAN Device shall support a registration method that employs cryptographic operations
772   (e.g., digital signatures).

773 12. Energy Services Interface shall provide an authentication mechanism which proxies for
774   the AMI System (e.g., negotiates on behalf of the Utility).

775 13. HAN Device shall provide notification to the Installer of the registration status. Status
776   conveyed shall be either: registered/not registered.

A.2.11 Performance (14)

777

778 1. HAN Device shall supply functionality that maintains communications availability to
779   the Energy Services Interface.

780 2. HAN Device shall supply functionality that maintains application availability to the
781   AMI System (e.g., software/hardware application watchdog).

782 3. After loss of power, HAN Device shall return to its post configuration state (i.e., shall
783   persist communication and registration configurations).

784 4. HAN Device shall supply adequate computational performance (i.e., Device shall not
785   hamper overall operational state of the HAN)

786 5. HAN Device shall supply adequate communications performance (e.g., bandwidth and
787   throughput).

788 6. HAN Device shall supply accurate time keeping and counter functions.

789 7. HAN Device shall not act on expired signals (e.g., message validity duration or
790   sequence).

791 8. HAN Device shall provide configurable communications such that the system is
792   scalable (e.g., heartbeat and request frequency).

793 9. For battery-powered HAN Devices, HAN Device shall function for a minimum of 1
794   year without requiring replacement of the battery.

795 10. HAN Device shall supply a field programmable software upgrade function (i.e.,
796   firmware upgrade).

797 11. HAN Device shall supply a remote software upgrade function (i.e., firmware upgrade).

798 12. HAN Device shall meet the quality, interoperability, and testing (i.e., certification)
799   requirements of its respective technology platform body.

800 13. HAN Device shall accept network time synchronization from the Energy Services
801   Interface.

802 14. Energy Services Interface shall accept time synchronization from a Utility-approved
803   source.

A.2.12 Operations, Maintenance, and Logistics; Manufacturing and Distribution (12)

806 1. Prior to installation (e.g., factory, depot), HAN Device shall support placement of
807   commissioning data (e.g., pre-placed device credentials).

808 2. Prior to installation (e.g., factory, depot), a HAN Device shall support placement of
809   registration data (e.g., pre-placed registration credentials).

810 3. HAN device shall support preplaced methods or materials that support commissioning
811   and registration by multiple Utilities (does not imply simultaneous Utility registration).

812 4. HAN Device shall support preplacement of application-specific configurations (e.g.,
813   cost, consumption, environmental impact, configurable time/rate intervals).

814 5. HAN Device shall have and display appropriate certification (e.g., electrical, safety, and
815   communications requirements) on its packaging or body.

816 6. HAN Device shall have and display appropriate commissioning and registration
817   information on its packaging and body (e.g., serial number, registration code).

818 7. HAN Device shall display Utility compatibility guidance to verify that a HAN Device is
819   compatible with a particular AMI system on its packaging.

820 8. HAN Device shall display its HAN network technology compatibility on its outside
821   packaging and body.

822 9. HAN Device shall display UtilityAMI compliance on its packaging.

823 10. HAN Device shall display Enhanced UtilityAMI compliance on its packaging.

824 11. The HAN device shall display, on its packaging, any secondary device requirements
825   (e.g., required EMS, bridge device).

826 12. HAN Device shall be manufactured to support multiple distribution channels (e.g.,
827   retail, direct Utility).

A.2.13 Operations, Maintenance, and Logistics; Installation (4)

829 1. HAN Device Manufacturer shall include installation documentation that includes
830   instructions for installation (e.g., placement), commissioning, and registration, including
831   any external dependencies.

832 2. HAN Device Manufacturer shall include a HAN Device user's manual in the Device
833   packaging.

834   3.   HAN Device Manufacturer shall include Manufacturer contact information in the
835   Device packaging.

836   4.   HAN Device Manufacturer shall supply technical support services (e.g., help desk, web
837   site).

838 *A.2.14 Operations, Maintenance, and Logistics; Manage and Maintain*
839 *(10)*

840   1.   HAN Device shall have a selfcheck (i.e., initialization) function that notifies the Installer
841   that the HAN Device is functioning properly.

842   2.   Energy Services Interface shall have a configurable ability to log all AMI System-to-
843   HAN System communications.

844   3.   When the HAN Device is rebooted, HAN device shall reset to its configured (i.e., post-
845   installation commissioning and registration) state and shall reestablish communication
846   with the Energy Services Interface.

847   4.   HAN Device shall have a user operable testing function that is equivalent to the self-
848   testing function.

849   5.   HAN Device shall supply a maintenance port for field diagnostics.

850   6.   HAN Device shall simulate Utility events for diagnostic purposes.

851   7.   HAN Device shall supply network management functions for diagnostic purposes.

852   8.   For battery-powered devices, HAN Device shall communicate low battery state to the
853   AMI System.

854   9.   HAN Device Manufacturer shall supply and support a flaw remediation process.

855   10. HAN Device shall support a communications feedback mechanism (i.e., ping).